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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
1a. UN		1b. RESTRICTIVE MARKINGS			
2a. AD-A206 320		3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.			
2b.		4. PERFORMING ORGANIZATION REPORT NUMBER(S) USARIEM-M16-89			
5. MONITORING ORGANIZATION REPORT NUMBER(S)		6a. NAME OF PERFORMING ORGANIZATION US Army Research Institute of Environmental Medicine			
6b. OFFICE SYMBOL (If applicable) SGRD-UE-PH		7a. NAME OF MONITORING ORGANIZATION Same as 6a.			
6c. ADDRESS (City, State, and ZIP Code) Kansas St. Natick, MA 01760-5007		7b. ADDRESS (City, State, and ZIP Code)			
8a. NAME OF FUNDING/SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (If applicable)		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS (City, State, and ZIP Code)		10. SOURCE OF FUNDING NUMBERS			
		PROGRAM ELEMENT NO.	PROJECT NO. BE162787A87	TASK NO. 879/BF	WORK UNIT ACCESSION NO. 133
11. TITLE (Include Security Classification) Physical Fitness and Infantry Operations					
12. PERSONAL AUTHOR(S) Joseph Knapik, William Daniels, Michelle Murphy, Patricia Fitzgerald, Frederick Drews, James Vogel					
13a. TYPE OF REPORT Manuscript		13b. TIME COVERED FROM July 83 TO Aug 83		14. DATE OF REPORT (Year, Month, Day) December	
15. PAGE COUNT 26					
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP	Anaerobic capacity, Wingate test, Thorstensson test, muscular strength, isometric, isokinetic, maximal oxygen uptake, body composition, field performance.		
19. ABSTRACT (Continue on reverse if necessary and identify by block number) Male infantry soldiers (N=34) were studied before, during, and after a 5 day simulated combat exercise. During the exercise, subjects were rated on their field performance by senior infantry non-commissioned officers. Prior to the exercise, direct measures of body composition and maximal oxygen uptake were obtained. Before and after the exercise the Army Physical Fitness Test (APFT) and various measures of anaerobic capacity (Wingate and Thorstensson tests) and muscular strength (isometric and isokinetic) were obtained. Results showed no significant decrement in field performance during the exercise. Upper body anaerobic capacity and strength declined following the exercise although the results for upper body strength were not consistent on all measures. Field performance was significantly correlated with measures of upper body anaerobic capacity and strength. Upper body strength and anaerobic capacity appear to be important for infantry operations and subject to declines during combat operations. <i>Keywords:</i>					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION		
22a. NAME OF RESPONSIBLE INDIVIDUAL			22b. TELEPHONE (Include Area Code)		22c. OFFICE SYMBOL

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Physical Fitness and  
Infantry Operations

RUNNING HEAD: Fitness in Infantry Operations

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## ABSTRACT

Male infantry soldiers (N=34) were studied before, during, and after a 5 day simulated combat exercise. During the exercise, subjects were rated on their field performance by senior infantry non-commissioned officers. Prior to the exercise, direct measures of body composition and maximal oxygen uptake were obtained. Before and after the exercise the Army Physical Fitness Test (APFT) and various measures of anaerobic capacity (Wingate and Thorstensson tests) and muscular strength (isometric and isokinetic) were obtained. Results showed no significant decrement in field performance during the exercise. Upper body anaerobic capacity and strength declined following the exercise although the results for upper body strength were not consistent on all measures. Field performance was significantly correlated with measures of upper body anaerobic capacity and strength. Upper body strength and anaerobic capacity appear to be important for infantry operations and subject to declines during combat operations.

Index Terms: Anaerobic capacity, Wingate test, Thorstensson test, muscular strength, isometric, isokinetic, maximal oxygen uptake, body composition, field performance.

## INTRODUCTION

Physical fitness has historically been associated with success on the battlefield (17). This has recently been underlined by the British experience in the Falkland Islands and the United States experience in Grenada. The British emphasis on hard physical training was cited as an important factor in the success in the Falklands (2) and physical fitness was listed as an important aspect of preventive medicine during the campaign (15). In Grenada, the infantry soldiers' load was excessive requiring a high level of fitness (7).

While the value of physical fitness is not questioned by most military observers (17), little scientific information is available regarding which components of physical fitness are most valuable or the magnitude of the relationship between fitness and soldiering tasks. Previous studies on infantry operations have focused largely on the influence of sleep loss on vigilance and psychomotor performance (3,10,18).

This study was designed to investigate the role of physical fitness in infantry operations (1). Tests measuring various components of physical fitness were administered to soldiers before and after a realistic combat scenario and related to evaluations of field performance. The components of fitness examined included aerobic capacity, body composition, anaerobic capacity, and muscle strength.

## MATERIAL AND METHODS

### SUBJECTS

Subjects were 34 male infantry soldiers assigned to the 9th Infantry Division at Ft. Lewis, WA. They represented 4 intact rifle squads although it was necessary to make several substitutions in the squads due to other requirements.

Thus, for the most part the subjects knew one another and were experienced in working together as a squad.

The soldiers' physical characteristics are shown in Table 1. After a medical screening, subjects were briefed regarding the purpose and risks of the study and gave their informed, voluntary consent to participate.

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TABLE 1 HERE  
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#### STUDY DESIGN

The study utilized a pretest, post test design with a simulated combat operations exercise interposed between the two tests. Pretesting was conducted 3-5 days before the exercise and post testing the morning immediately following the exercise.

#### FIELD EXERCISE

The field exercise consisted of 5 consecutive days of infantry operations requiring both offensive and defensive maneuvers on foot. The terrain consisted of heavily wooded land with medium to thick underbrush. The maximum difference in elevation was 60 feet. There were 4 major terrain areas. On each day the 4 squads operated independently in these and rotated through them with one area repeated. Two to 4 specific missions were conducted at each area. Missions and the situations attached to each are shown in Table 2. These were based on events described more fully in the Army Test Program (ARTEP) T-15 (5). All squads began the exercise with a 10 km road march out to the appropriate terrain area. Four hours of sleep were permitted each night.

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TABLE 2 HERE  
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A medic traveled with each squad for safety purposes but did not participate in the exercise. Soldiers carried all necessary equipment and supplies for 5 days; however, every 24 hours, a food (field rations) and ammunition (blanks) resupply was conducted at a predetermined location. Pack weights were between 9-13 kg and a radio-telephone operator (one per squad) carried a radio weighing 9 kg.

APPARATUS AND PROCEDURES

Field Performance Scores

Senior infantry non-commissioned officers (NCO's) served as evaluators during the exercise. Two NCO's traveled with each squad and were rotated on a 12 hour basis. They rated performance on each mission (mission score) as either successful ("GO") or unsuccessful ("NO GO") based on ARTEP standards (5). They also rated the performance of each squad and each squad member at the conclusion of each mission using a subjective 10 point scale. These scores were called either the squad performance score or individual performance score.

Pretest and Post Test

Subjects were required to perform an Army Physical Fitness Test (APFT, 6). They completed as many push-ups as possible in 2 minutes; they also completed as many sit-ups as possible in 2 minutes. They ran 2 miles as rapidly as possible. A composite APFT score (maximum possible 300 points) was calculated using Army standards (6).

Subjects fired M-16 rifles at targets on a standard Army firing range. Targets were pop-up silhouettes which were shot down as they appeared. Each subject was provided forty rounds of ammunition and a score of 1 point was given for each target hit. This was called the record fire test.

Aerobic capacity ( $\dot{V}O_{2\max}$ ) was measured using a discontinuous, incremental treadmill protocol (23). Subjects ran at 6 miles $\cdot$ hr $^{-1}$ , 0% grade for 6 min followed by a 5-10 min rest. Two to 4 additional runs were performed, each 3 to 4 min in length and interrupted by rest periods. During the last minute of each run, expired gases were collected into vinyl bags. Oxygen and carbon dioxide were measured with a fuel cell and infrared analyzer, respectively, and gas volumes with a Tissot spirometer.

Body density was determined by a seated underwater weighing procedure (8). Percent body fat was calculated from the Siri equation (21). Residual lung volume was estimated on land as 25% of the vital capacity measured in a seated position.

Anaerobic capacity of the upper and lower body was measured using the Wingate (9) and Thorstensson (22) tests. The Wingate test was performed on a modified Monarch cycle ergometer. It consisted of 30 seconds of maximal arm or leg pedalling against a resistance relative to the body weight of the subject. Resistances were 0.075 kg/kg body weight for the lower body and 0.050 kg/kg body weight for the upper body. Peak power was the power output of the highest 5 second period (usually the first 5 seconds). Average power was the mean power over the entire 30 second period.

The Thorstensson test was conducted on a modified Cybex II<sup>R</sup> device (20). Subjects performed 50 rapidly repeated contractions of the elbow flexors or knee extensors at a velocity of 180° $\cdot$ sec $^{-1}$ . Subjects were instructed to pull or kick up

"as hard and as fast as possible", relax on the way down, then immediately pull or kick up again. Maximal peak torque was the average of the 4 highest torque values for the 50 contraction test. Average peak torque was the mean torque for the 50 contractions. Average peak torque was calculated in a similar manner for the first 20 contractions (elbow flexors) or the first 25 contractions (knee extensors).

Concentric (isokinetic) strength of the elbow flexors and knee extensors was measured on a modified Cybex II<sup>R</sup> device (20) at velocities of 30 and 180° • sec<sup>-1</sup>. After two submaximal contractions, maximal voluntary efforts were elicited for each muscle group at both velocities. Isometric strength was also measured for these muscle groups (0° • sec<sup>-1</sup>). Each contraction was separated by a rest period of at least 30 seconds and the mean of three scores was used for data analysis.

Strength testing included an isometric evaluation of the upper torso (UT), legs-hips (LH), trunk extensors (TE), handgrip (HG) and upright pull (UP) using tests that have been developed in this laboratory (12,13). Three maximal contractions of 3-4 seconds duration were averaged for data analysis. Each contraction was separated by a rest period of at least 30 seconds.

Dynamic lifting capacity was measured by having subjects lift a rack of weights to a height of 183 cm (16). Subjects started in a squat position, bending at the knees, and grasped the handles of the device. The first weight lifted was 18 kg and the load was increased on each subsequent lift by 9 kg until the subject had difficulty lifting. The weight was then incremented by 4.5 kg units until the subject could not achieve the proper height. The final score was the heaviest load lifted to 183 cm.

All testing was conducted with the goal of minimizing the confounding influence of fatigue due to repetitive testing of the same muscle groups. Aerobic

capacity, body composition and 3 isometric strength tests (UT, LH, TE) were measured only on the pretest. The APFT, record fire and the Thorstensson and Wingate tests were measured on both the pretest and post test. About half of the subjects were tested on the upper body Wingate test and the lower body strength and Thorstensson test; other subjects were tested on the lower body Wingate test and the upper body strength and Thorstensson test.

### STATISTICAL ANALYSIS

Pretest and post test measures were compared using a Student's t-test. The relationship between the performance scores and the laboratory and field tests were examined using Pearson product moment correlation coefficients. The 0.05 level of statistical significance was chosen.

### RESULTS

During the exercise, outdoor temperatures ranged from 11-31° C with an average of about 18° C. Total precipitation was 1.0 cm with 0.9 cm falling on the third day. Table 3 shows the mission scores averaged for all 4 squads. Squads received a "GO" on 73% of the events overall and there was no apparent decrement in the proportion of "GO" to "NO GO" ratings over days. Squad performance scores appear to decrease over days but this trend was weak and not statistically significant. The individual performance scores averaged (mean  $\pm$  SD)  $6 \pm 1$  with a range of 4 to 7.

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TABLE 3 HERE  
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Table 4 presents results from the 2 administrations of the APFT and record fire. The most striking feature of Table 4 was the consistent, significant performance decrement on all of the APFT events. Record fire was unaffected by participation in the exercise.

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TABLE 4 HERE  
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Figures 1 and 2 depict changes in the upper and lower body, respectively, for the 2 tests of anaerobic capacity (Wingate and Thorstensson tests). All upper body anaerobic measurements showed declines on the post test and this was statistically significant for 3 of 5 measurements. The lower body (Figure 2) did not present as clear a picture. Three of the 5 measures showed increased performance but only 1 was statistically significant; the other 2 showed decreased performance with one of these statistically significant.

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FIGURES 1&2 HERE  
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Figure 3 shows the results of the elbow flexion and knee extension strength tests. There were statistically significant declines in strength of the elbow flexors from pretest to post test at all 3 velocities. While the knee extensors generally showed declines in strength also, this was statistically significant only at the  $30^{\circ} \cdot \text{sec}^{-1}$  velocity.

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FIGURE 3 HERE  
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On the pretest, average ( $\pm$ SD) values obtained for the UT, LH, and TE were  $103 \pm 20$  kg,  $186 \pm 77$  kg, and  $89 \pm 26$  kg, respectively. Figure 4 depicts changes in 3 other strength indices. While there was no significant change in upright pull strength, both the handgrip and dynamic lifting test demonstrated statistically significant increases from pretest to post test.

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FIGURE 4 HERE  
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Table 5 shows the statistically significant correlations between the individual performance scores and other pretest and post test measurements. Measurements not shown in Table 5 did not reach statistical significance. Two upper body anaerobic capacity measures had the highest correlations with the individual performance measure. A stepwise multiple linear regression was performed using the individual performance score as the dependent variable. Peak power on the upper body Wingate test and record fire accounted for a significant portion of the variance ( $p < 0.05$ ) with a multiple R value of 0.58.

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TABLE 5 HERE  
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## DISCUSSION

### PRETEST AND POST TEST MEASUREMENTS

A major finding of the present study was the reduced upper body anaerobic capacity and strength following the 5 day field exercise. Decrements were seen for both the upper body Thorstensson and Wingate tests as well as for push-ups

and sit-ups. The Thorstensson and Wingate tests have been shown to be highly correlated with other measures of anaerobic capacity (19), and push-ups and sit-ups show high factor loadings for upper body and trunk strength and endurance (24). Results on the Wingate test are in consonance with the findings of Legg and Patton (14) following an 8 day continuous field artillery exercise.

Findings for specific upper body strength measures were not consistent. While elbow flexion strength showed decrements at all 3 velocities, there were actually significant increases in handgrip and dynamic lift strength. Results of the dynamic lift were particularly impressive and may be partially explained by strong verbal motivation on the part of the subjects. Soldier morale was high at the conclusion of the exercise and soldiers often cheered one another during the dynamic lift. They did not do this on the pretest. Controlled studies on the influence of motivational factors on human muscle strength suggest that strength can be increased in this manner (11).

Lower body strength (knee extensors) also declined after the exercise but, the lower body anaerobic test results were mixed. There were post test increases on the Wingate test and both declines and increases on the Thorstensson test. Legg and Patton (14) reported similar findings for the Wingate test and suggested their 8 day exercise may have resulted in a training effect.

A major contributor to the declines in upper body exercise capacity and lower body strength may have been the loads carried by the soldiers. Field observations made by the evaluators, medics and research team suggested that some soldiers had difficulty carrying their packs. Subjects had additional difficulty when required to carry the radio plus their regular load; others had problems carrying a man on a litter (required during some missions). Medics reported that some subjects developed back problems during the exercise (1,4).

These findings may suggest the need for increased physical training of the upper and lower body.

Record fire scores showed no change after the field exercise. Opstad et al. (18) and Banks et al. (3) also demonstrated that shooting tasks did not deteriorate during 2 to 4 days of sustained operations with little sleep. These observations support the hypothesis of Haslam (10) that simple, well learned tasks do not degrade during continuous operations at least up to 4-5 days.

#### RELATIONSHIP OF PRETEST MEASUREMENTS TO FIELD PERFORMANCE

A second major finding of the present study was the relationship between the individual performance scores and the physiological measurements. While correlations were run between all measurements and the performance scores, the only significant correlations involved record fire and 5 upper body anaerobic and muscle strength measures. It would appear that upper body exercise capacity is important for infantry operations and is subject to decrements during field operations.

It should be noted that although the correlations in Table 5 are statistically significant, they are still relatively low, the largest accounting for no more than 21% of the variance in the performance score. One reason for this may be the inadequacy in the rating procedure. Although the scale for the performance score ranged from 1 to 10, the evaluators actually utilized a scale ranging from 4 to 7. This could be due to the similarities in the capabilities of the soldiers. They had all received similar field training and this could have blunted the discriminatory power of the scale because of reduced between-subject variability. A field performance measure that resulted in a wider range of scores and/or a more

objective assessment of soldier performance may have demonstrated stronger relationships.

In multiple regression analysis, peak power on the upper body Wingate test and record fire were shown to make independent contributions to the variance in the individual performance score. Accuracy in live firing of weapons was not required during the exercise. The relationship between record fire and performance may reflect skillful overall soldiering practices.

There was no significant relationship between aerobic capacity and field performance as measured here. The  $\dot{V}O_2$ max values were high compared to previous samples (23), indicating a high level of aerobic fitness for our subjects. The missions required in the exercise were probably not of sufficient intensity to cause the cardiovascular system to be a limiting factor.

Performance during the field exercise as evaluated by ARTEP standards and squad performance scores did not degrade during the 5 day scenario. Apparently, with 4 hours of sleep squads can effectively conduct military missions at the intensity performed here.

## CONCLUSION

The present study has documented significant declines in upper body strength and anaerobic capacity consequent to participation in a 5 day infantry field exercise. Also, significant correlations were found between subjective evaluations of field performance and upper body strength and anaerobic capacity. These results demonstrate the importance of upper body exercise capacity for successful infantry operations and suggest that physical training of the upper body should be emphasized.

### ACKNOWLEDGMENTS

Appreciation is expressed to Rose Wildgoose, Linda Suek, Bob Mello, David Burnell, and Eric Bertrand who provided technical support. Bruce Jones, M.D. served as medical monitor. Thanks also to Kim Eckert and Beth Reichert for word processing of the manuscript.

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TABLE 1  
PHYSICAL CHARACTERISTICS OF THE SUBJECTS (n=34)

	Age	Height	Weight	Body Fat	Fat Free Mass	VO <sub>2</sub> max
	(yrs)	(cm)	(kg)	(%)	(kg)	(ml • kg <sup>-1</sup> • min <sup>-1</sup> )
M	22	172.9	72.8	14.1	62.5	53.6
SD	3	7.5	10.6	6.9	10.4	5.6
Range	18-29	155.8-189.9	50.1-99.4	2.7-29.2	41.5-84.2	44.2-63.3

TABLE 2  
TERRAIN AREAS, MISSIONS, AND  
TIME OF DAY (24 HOUR CLOCK) FOR FIELD EXERCISE

<u>Terrain Area</u>	<u>Mission/Situations</u>	<u>Time</u>
1	Raid/React to NBC*; React to Mortar Fire; Establish Rally Point	0600
	Road Block and Vehicular Ambush	1300
	Point Reconnaissance and Raid/React to NBC*; Establish Rally Point	1700
	Establish Patrol Base	2300
	Stand Down	0100
	Stand To and Move to Resupply Point	0500
2	Area Reconnaissance/Establish Rally Point; Process POW**	0600
	Defend Two Hills/React to Sniper; React to Enemy Fire; Withdraw Under Pressure	1500
	Stand Down	0100
	Stand To and Move to Resupply Point	0500
3	Movement to Contact/React to Sniper; Process POW**; Evacuate Wounded	0630
	Vehicular Ambush	1100
	Area Reconnaissance/Locate Enemy Outpost; Attack and Seize; Defend Outpost	1400
	Establish Patrol Base	2230
	Stand Down	0100
	Stand To and Move to Partisan Link-Up	0500
4	Partisan Link-Up/Raid; Evacuate Wounded	0800
	Secure and Hold Landing Strip/React to Enemy Fire; Fire on Landing Strip	1600
	Stand Down	0100
	Stand To and Move To Resupply Point	0500

\*NBC=NUCLEAR, BIOLOGICAL AND CHEMICAL AGENTS

\*\*POW=PRISONER OF WAR

TABLE 3  
RATINGS ON EXERCISE EVENTS

Mission Scores

Day	"GO" (No.)	"NO GO" (No.)	Squad Performance Score
1*	11	4	6.6
2	7	4	6.6
3	7	4	5.0
4	10	1	6.2
5	8	3	5.4

\* Mission scores on Day 1 included the 10 km road march for which all squads received a "GO".

TABLE 4  
APFT AND RECORD FIRE

	N	Pretest		Post test		%	t-Value
		M	SD	M	SD		
Sit-ups (reps)	33	66.8	10.7	61.6	10.4	-7.8	4.85**
Push-ups (reps)	33	66.0	12.3	59.8	14.9	-9.4	4.10**
2 mile run (min)	33	14.4	1.7	15.6	1.9	-8.3	5.11**
APFT Score (points)	33	269	28	247	35	-8.2	6.45**
Record fire (hits)	32	27.6	4.4	27.5	6.7	-0.4	0.11

\*\* Statistically Significant,  $P < .01$

TABLE 5  
CORRELATION COEFFICIENTS BETWEEN SCENARIO  
PERFORMANCE SCORE AND PRETEST PARAMETERS

Variable	Correlation Coefficient
Peak Power Wingate Upper Body	0.46**
Average Power Wingate Upper Body	0.43**
Record Fire	0.41*
Upper Torso	0.36*
Upright Pull	0.36*
Incremental Dynamic Lift	0.36*

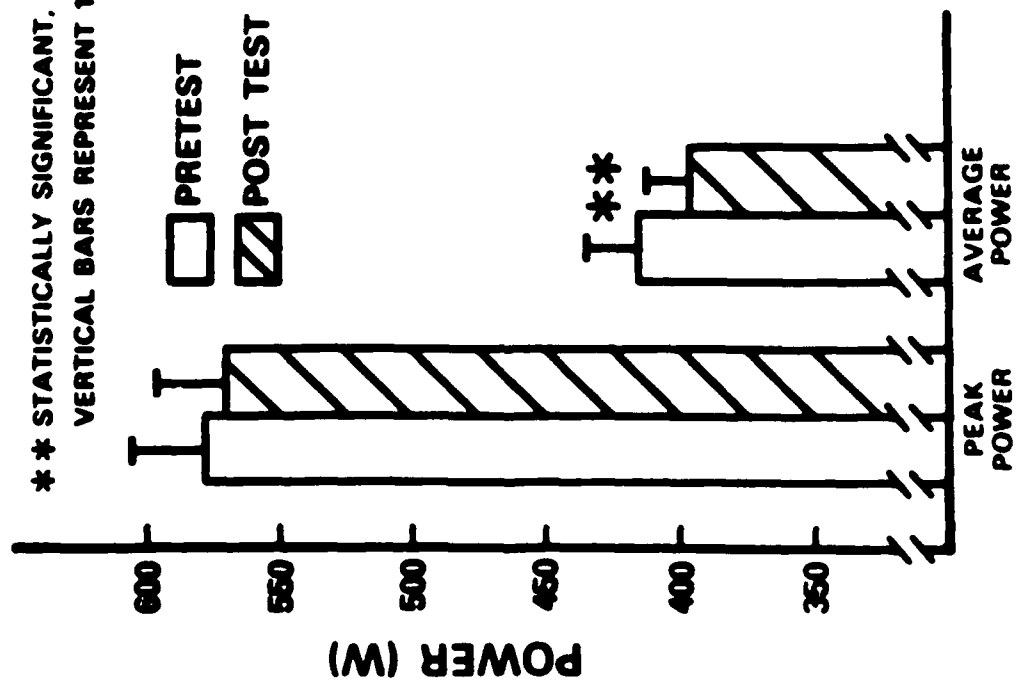
\*\* Statistically significant,  $p < .01$

\* Statistically significant,  $p < .05$

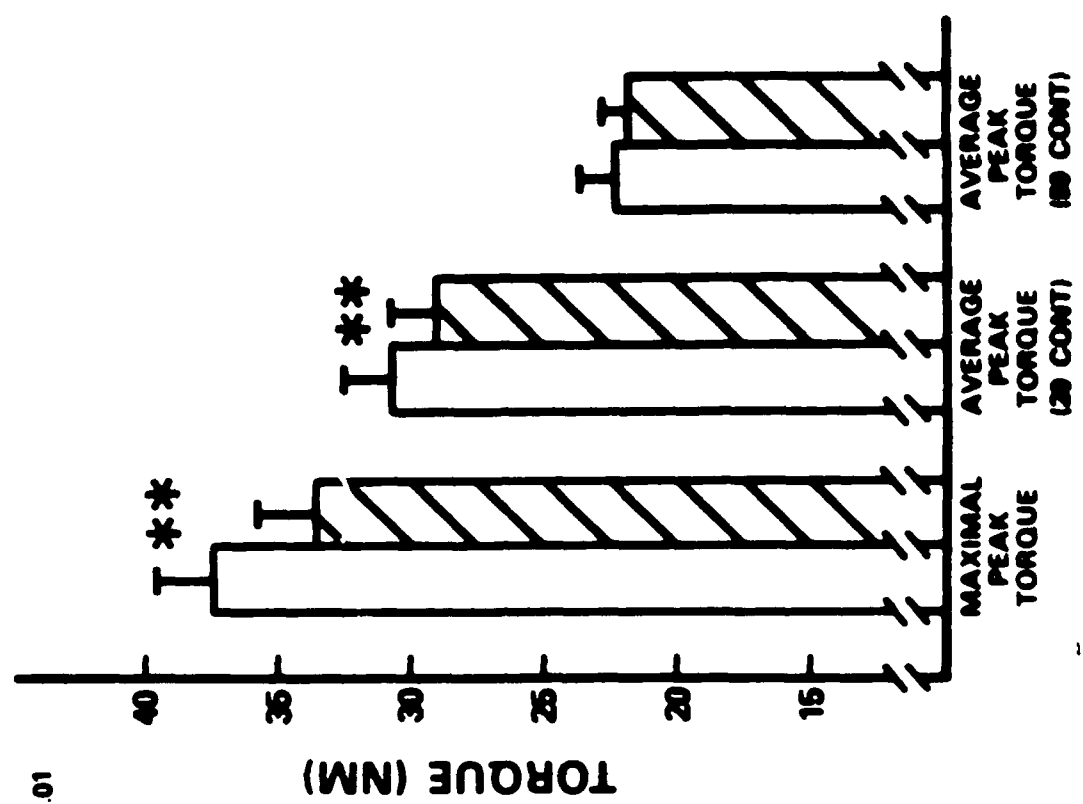
## FIGURE LEGENDS

- Figure 1. Anaerobic Capacity of the Upper Body ( $M \pm SE$ )
- Figure 2. Anaerobic Capacity of the Lower Body ( $M \pm SE$ )
- Figure 3. Elbow Flexion and Knee Extension Strength ( $M \pm SE$ )
- Figure 4. Upright Pull, Handgrip and Incremental Dynamic Lift  
Strength ( $M \pm SE$ )

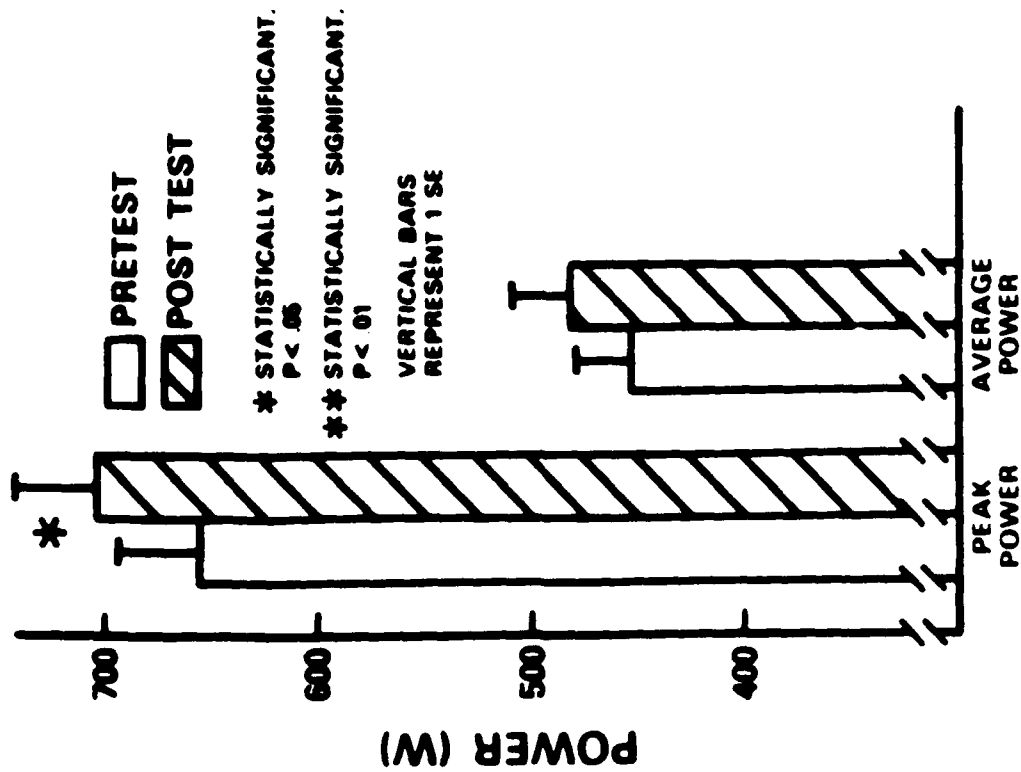
\*\* STATISTICALLY SIGNIFICANT,  $P < .01$   
 VERTICAL BARS REPRESENT 1 SE



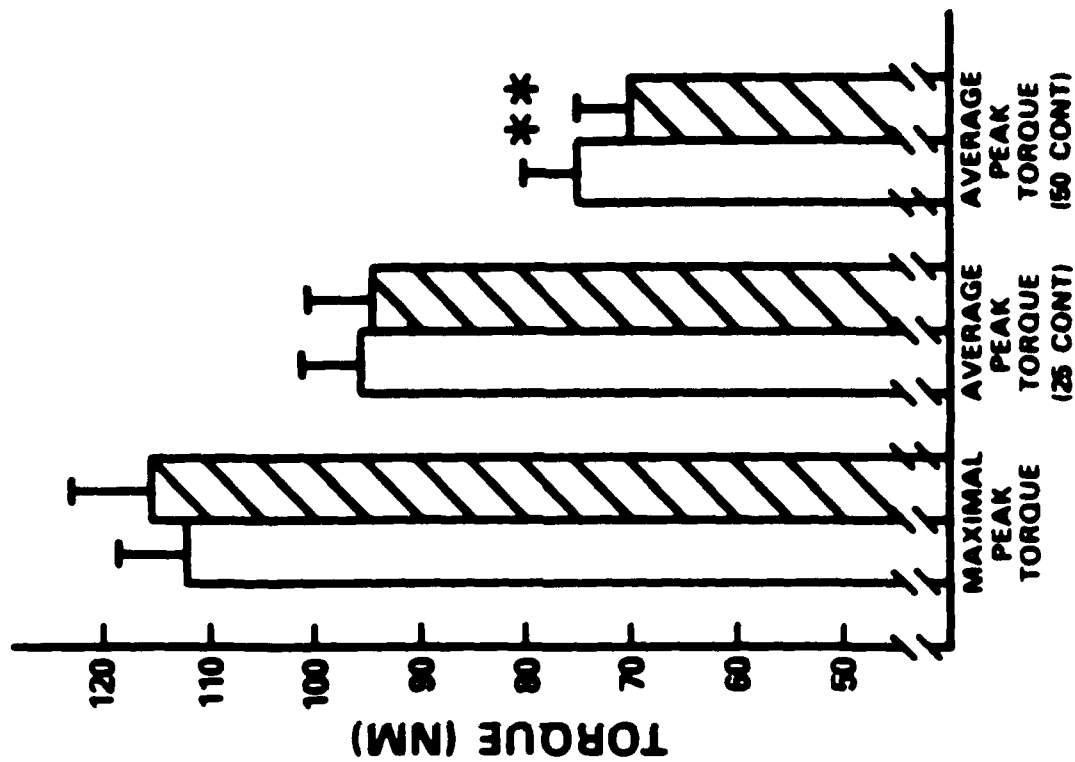
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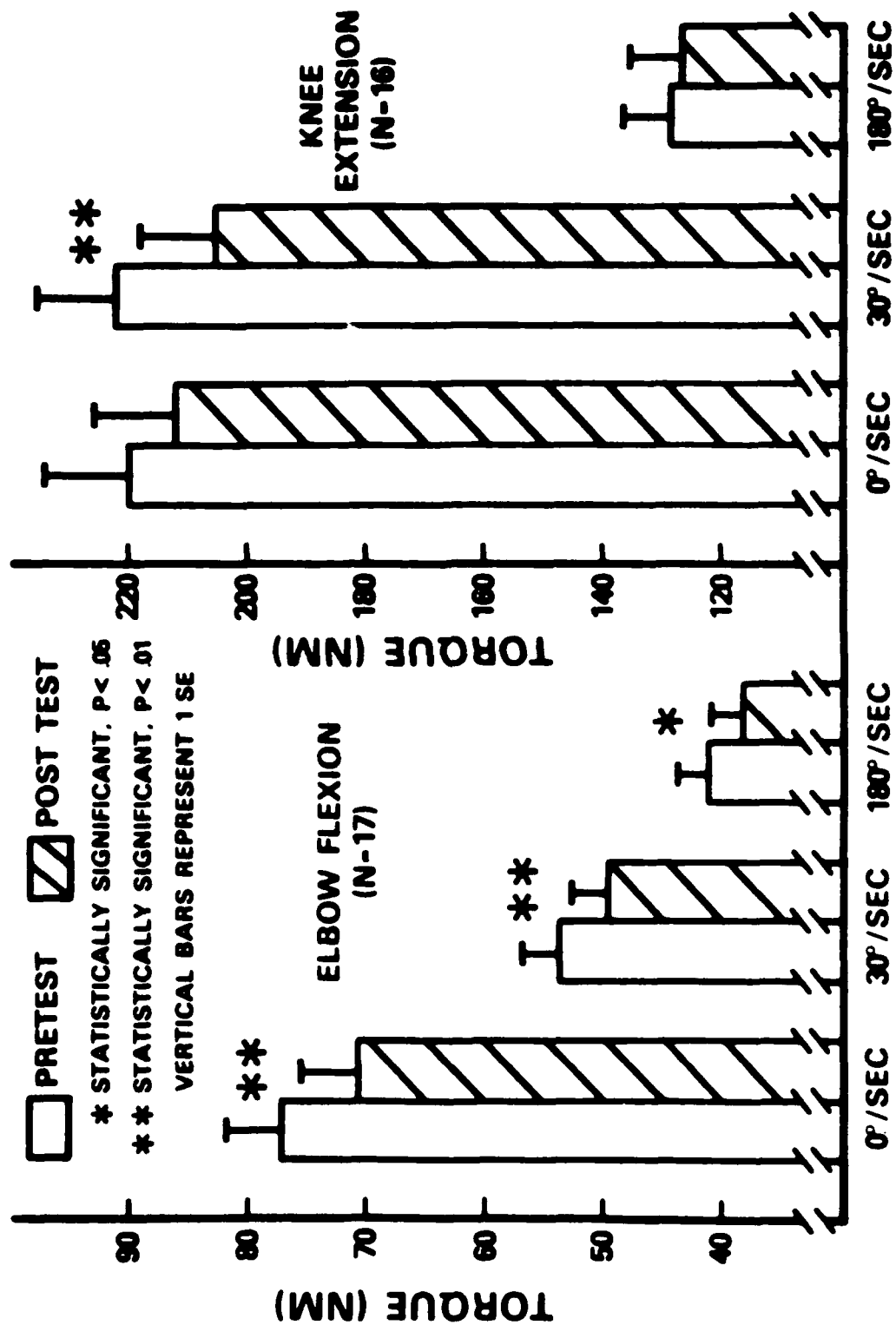
THORSTENSSON TEST (N-17)



WINGATE TEST (N-17)



THORSTENSSON TEST (N-16)



ISOKINETIC VELOCITY

